Sediment Budget Analysis System (SBAS): Upgrade for Regional Applications

by Julie D. Rosati and Nicholas C. Kraus

PURPOSE. This Coastal and Hydraulics Engineering Technical Note (CHETN) describes a major upgrade of the Sediment Budget Analysis System (SBAS) to include the capability to create and manage regional sediment budgets. The SBAS is a PC-based application for calculating and displaying local and regional sediment budgets including single and multiple inlets, estuaries, bays, and adjacent beaches. The SBAS runs on the Windows 95, 98, and NT operating systems. Features of the original SBAS Version 1.0 are discussed in Rosati and Kraus (1999a), and these features are also supported in SBAS Version 1.02, which covers regional processes. This CHETN introduces recent upgrades that support regional applications. A tutorial is available as discussed at the end of this technical note.

BACKGROUND. A regional characterization of coastal and riverine sediment transport rates and magnitudes, as well as the engineering activities within the region (dredging and placement of littoral resources), is a basic component in designing and evaluating the response of projects within the watershed. The regional sediment budget quantifies these natural sediment transport processes and anthropogenic activities. SBAS is a tool that allows multiple local (project-level) sediment budgets to be included within one or more regional sediment budgets. Features of SBAS have been implemented to facilitate creation and display of both the local and regional sediment budgets, as discussed herein. First, a review of sediment budget methodology is presented as summarized from Rosati and Kraus (1999b).

SEDIMENT BUDGET. A sediment budget is a tally of sediment gains and losses, or sources and sinks, within a specified control volume (or cell), or in a series of connecting cells, over a given time. There are numerous ways of formulating a sediment budget (US Army Corps of Engineers 1984, Jarrett 1991, Bodge 1999, Mann 1999). The algebraic difference between the sediment sources and the sinks in each cell, hence, for the entire sediment budget, must equal the rate of change in sediment volume occurring within that region, accounting for possible engineering activities. Expressed in terms of variables consistent as volume or as volumetric rate of change, the sediment budget equation is:

$$\sum Q_{source} - \Sigma Q_{sink} - \Delta V + P - R = \text{Residual} \qquad \text{Equation (1)}$$

where Q_{source} and Q_{sink} are the sources and sinks to the control volume, respectively, ΔV is the net change in volume within the cell, *P* and *R* are the amounts of material placed in and removed from the cell, respectively, and Residual represents the degree to which the cell is balanced. For a balanced cell, the residual is zero. Figure 1 schematically illustrates the parameters appearing in Equation 1, in which LST denotes longshore sediment transport. For a reach of coast consisting of many contiguous cells, the budgets for individual cells must balance in achieving a balanced budget for the entire reach.

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As noted in Figure 1, sources in the sediment budget include longshore sediment transport, erosion of bluffs, transport of sediment to the coast by rivers, erosion of the beach, beach fill and dredged material placement as from navigation channel maintenance, and a relative sea level fall. Examples of sediment budget sinks are longshore sediment transport, accretion of the beach, dredging and mining of the beach or nearshore area, relative sea level rise, and losses to a submarine canyon.
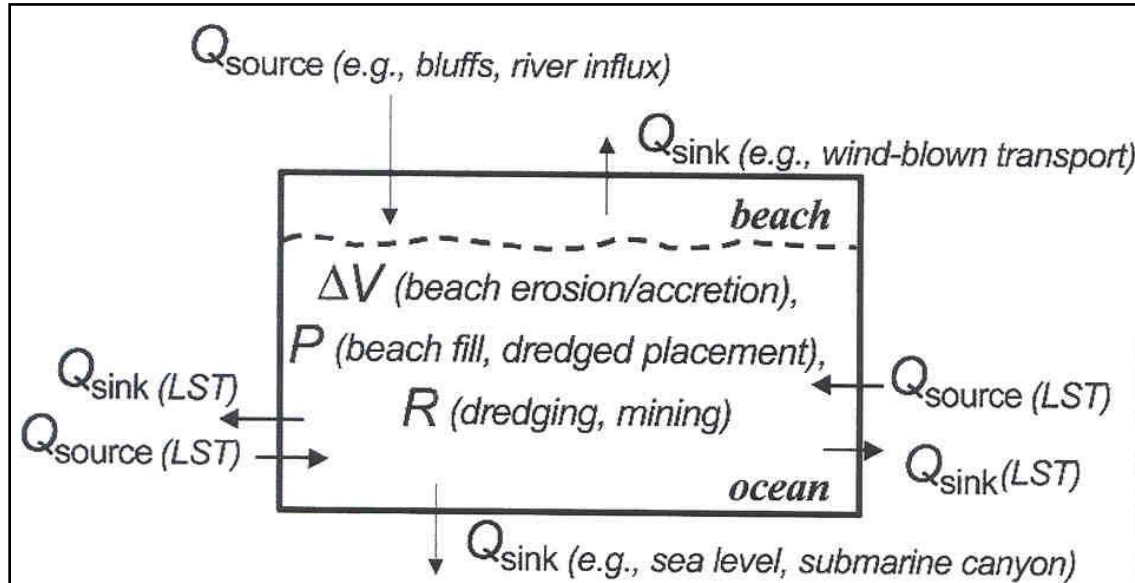

Figure 1. Sediment budget parameters that may enter Equation 1.

Longshore transport rates require two directions, which can be defined either through the pair of rates as left- and right-directed or as net and gross. The net longshore transport rate is defined as the difference between the right-directed and left-directed littoral transport over a specified time interval for a seaward-facing observer,

$$Q_{net} = Q_R - Q_L \qquad\qquad \text{Equation (2)}$$

in which the left-directed transport Q_L and right-directed transport Q_R are taken as positive. The gross longshore transport rate is defined as the sum of the right-directed and left-directed littoral transport over a specified time interval for a seaward-facing observer,

$$Q_{gross} = Q_R + Q_L \qquad\qquad \text{Equation (3)}$$

An inlet channel may capture much of the left- and right-directed components of the longshore transport, and the inlet system may bypass left- and right-directed longshore transport. Thus, knowledge of the net and gross transport rates, as well as pathways of sediment transport for left- and right-directed dominance (as might occur during seasons of net transport reversal), are required to accurately represent transport within the vicinity of inlets (Bodge 1993). The net or predominant direction of longshore sediment transport at an inlet or at a groin or jetty can usually be inferred by the asymmetry in geomorphology at the site (Carr and Kraus 2001). The asymmetry can be related to the ratio of net to gross longshore transport Q_{net}/Q_{gross} which varies from zero (balanced left- and right-directed longshore transport, hence near-symmetrical morphology) to unity (unidirectional longshore transport).

FEATURES OF SEDIMENT BUDGET ANALYSIS SYSTEM (SBAS). SBAS is operated within a graphic-based interface to solve Equation 1 for each cell and any combined cells. The user drags and pulls the mouse to form squares or rectangles (sediment budget cells), and to form arrows (sources and sinks) into and out of each cell (Figure 2). Volume changes (or volume change rates) are entered in the cell menu, which is accessed by double-clicking at a cell (Figure 3). Engineering activities (placement and removal volumes or rates) can be entered using the upper toolbar. Color-coding of the cells indicates whether the cell is balanced or not (Figure 4). Figure 5 details the functions of the upper and lower toolbars.
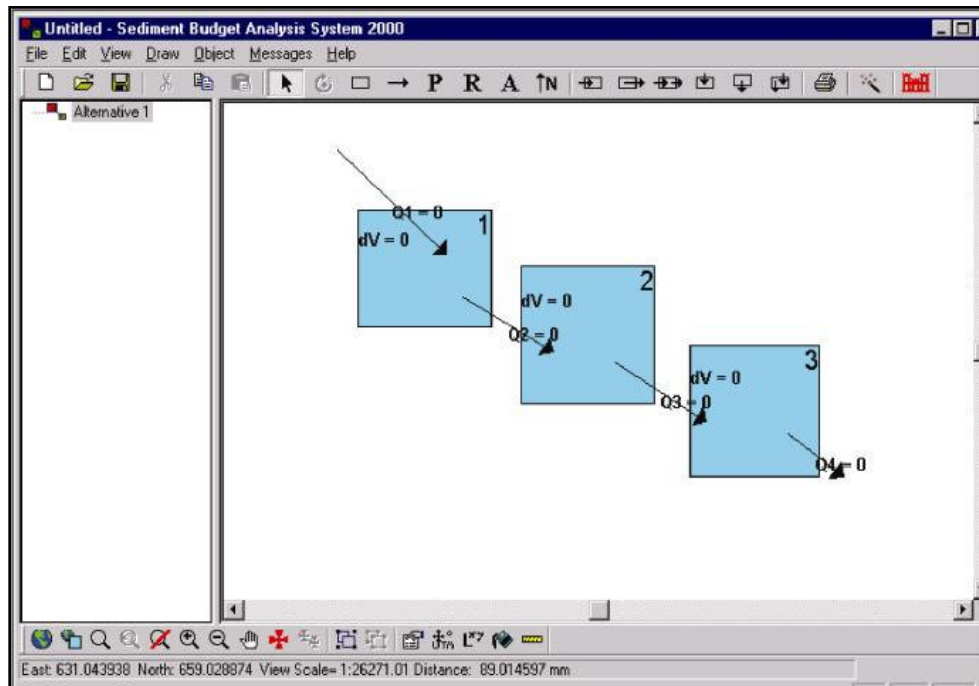

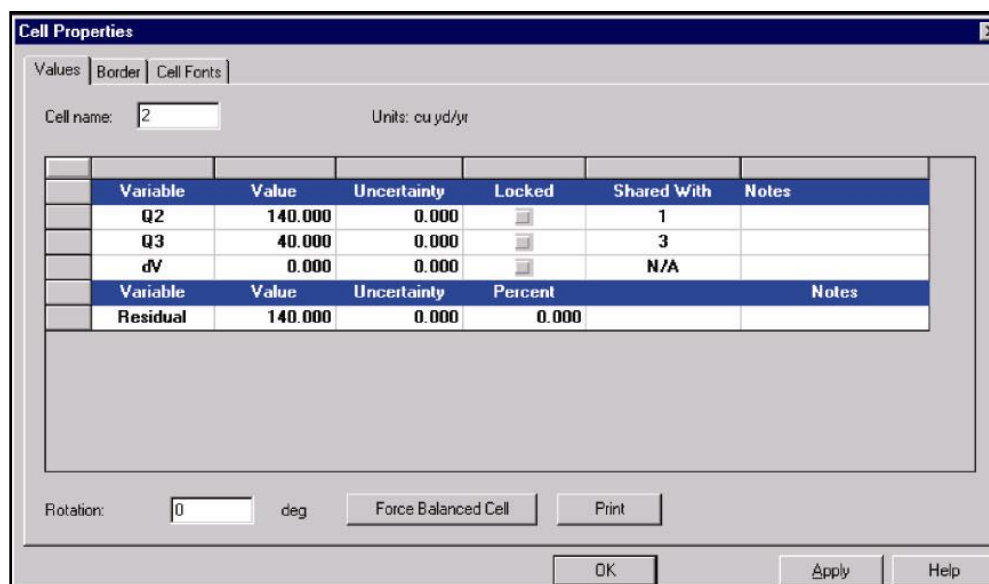**Figure 2. Creating sediment budget cells, sources, and sinks.**

Figure 3. Cell properties menu (accessed by double-clicking on a cell).
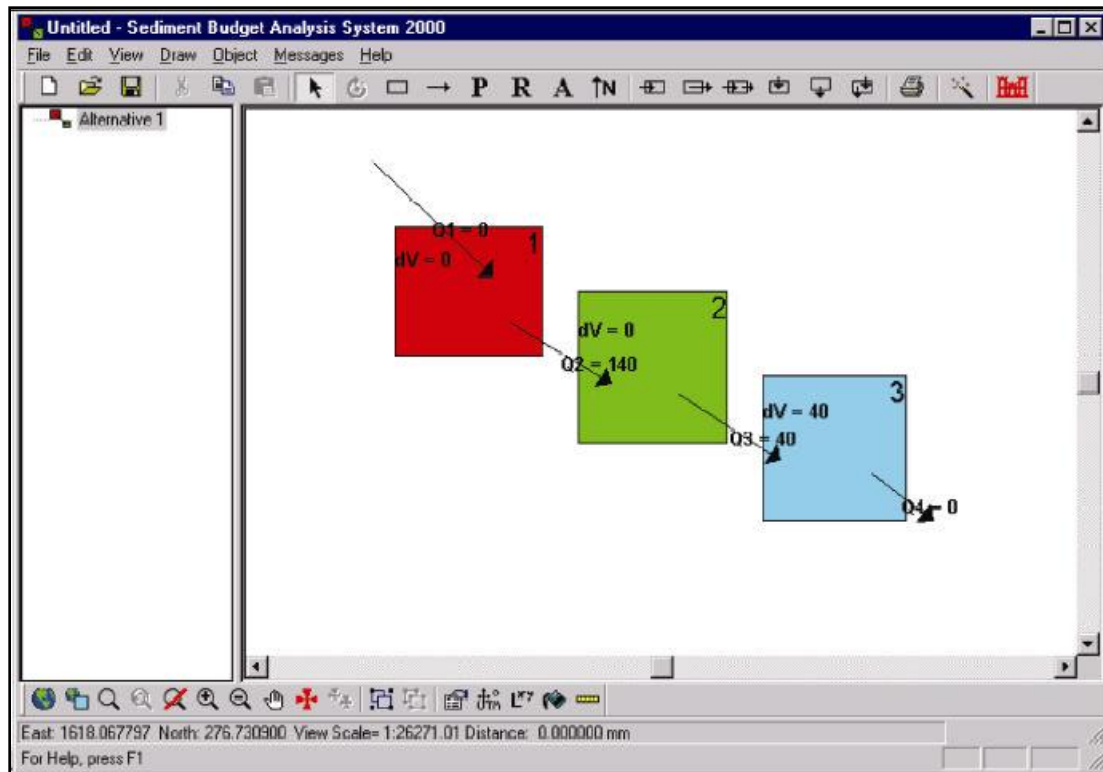
Figure 4. Color-coding indicates cell imbalance; Topology window (right-hand side), and Alternatives window (left-hand side).
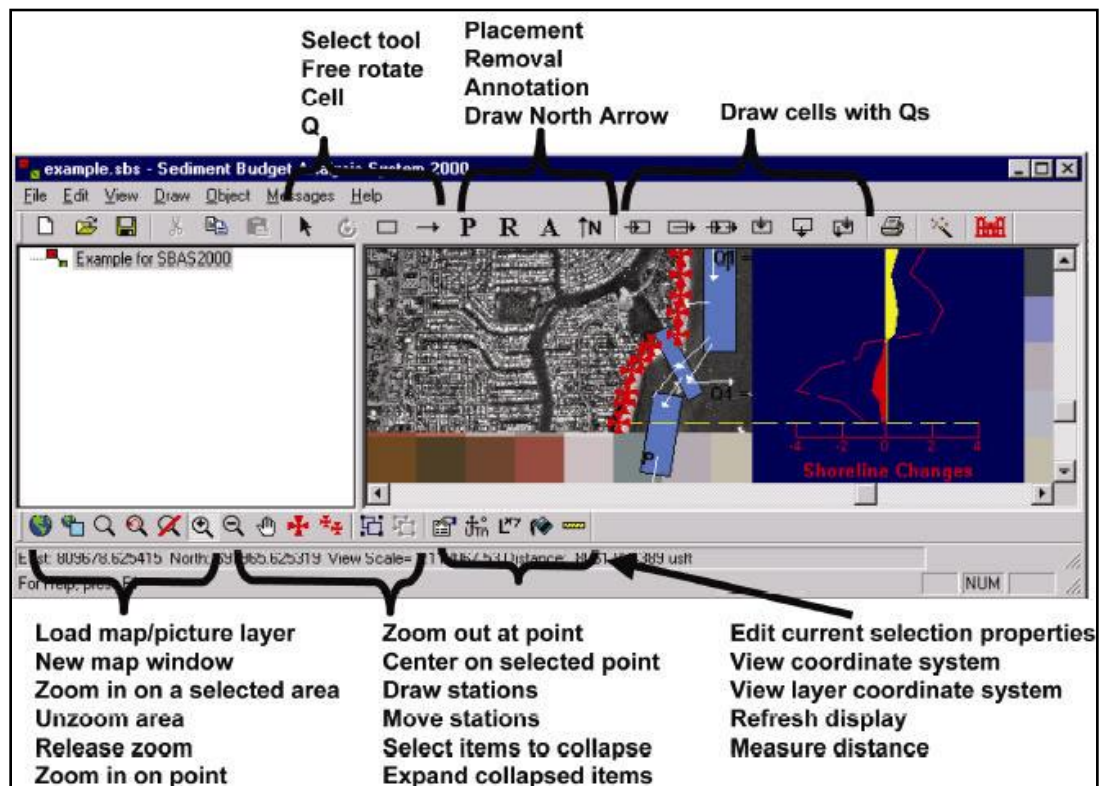

Figure 5. SBAS toolbars and button functions.

SBAS has been designed to organize the user's workspace and facilitate development and visualization of alternative sediment budgets. Within the right-hand side of the screen, called the *Topology* window (Figure 4, right-hand side), SBAS formulates a sediment budget by allowing the user to create a series of cells and arrows representing sources and sinks that characterize the budget. Elements can be selected conveniently from the upper toolbar to generate a sediment budget.

The left-hand side of the screen organizes alternatives within a particular project (Figure 4, left-hand side). Alternatives may represent various time periods, different boundary conditions for the same time period, or modifications to assumptions within the budget reflecting a sensitivity analysis. Once a sediment budget alternative has been defined, and the user has created sediment budget cells with sources and sinks, values can be assigned to the various components of the sediment-budget topology.

The lower toolbar allows the import of geo-referenced images and data into a desired coordinate system (Figure 5), which can beviewed with the sediment budget in the *Topology* window. The user can zoomout to view the regional sediment budget (see Figure 6, which shows the Gulf of Mexico shore of Alabama and Florida panhandle), and zoom in to show a detailed area (Figure 7). By dragging the cursor over any combination of cells, sediment budget cells can be combined ("collapsed"), as shown in Figure 7. A collapsed cell combines all sources and sinks for the selected cells, and is useful in regional views of a sediment budget. For local, project-level applications, selecting the collapsed cell and choosing an icon from the bottom toolbar will reinstate ("explode") the collapsed cell (Figure 8).
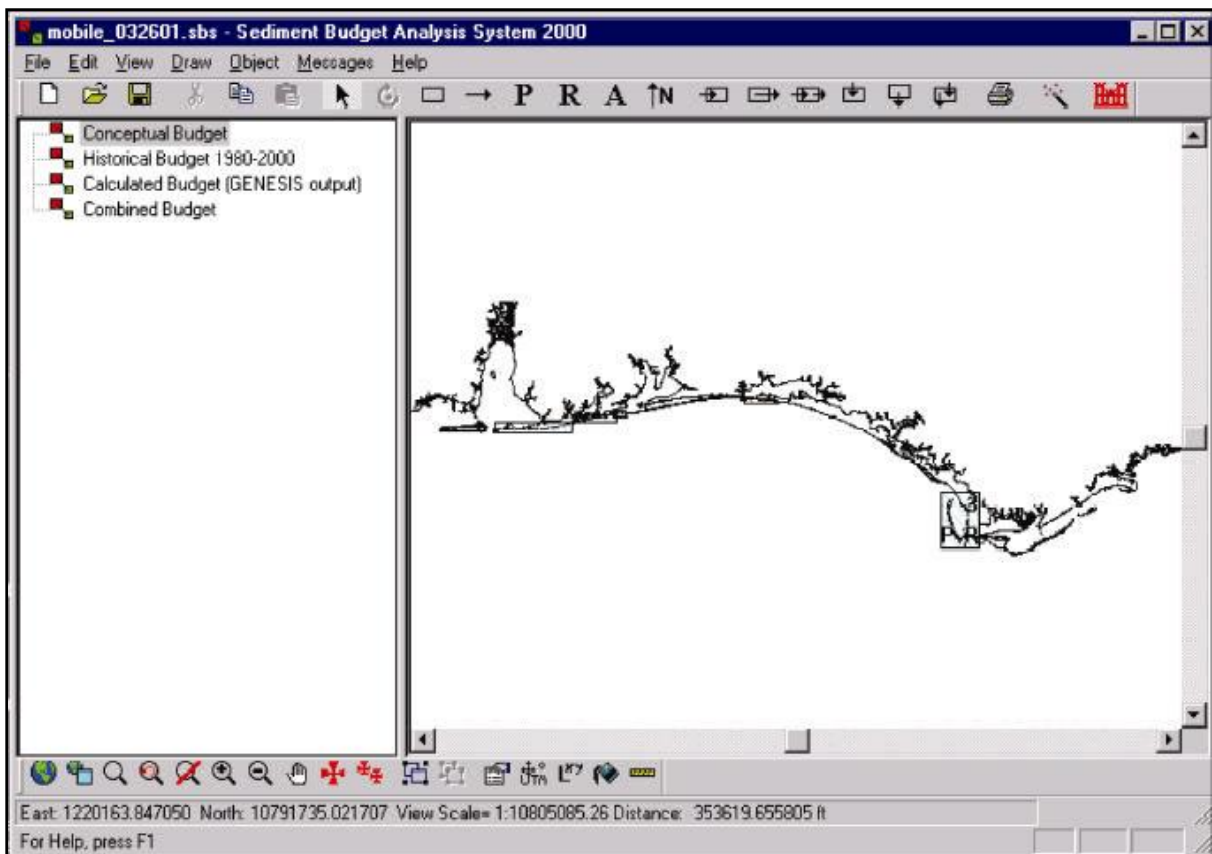

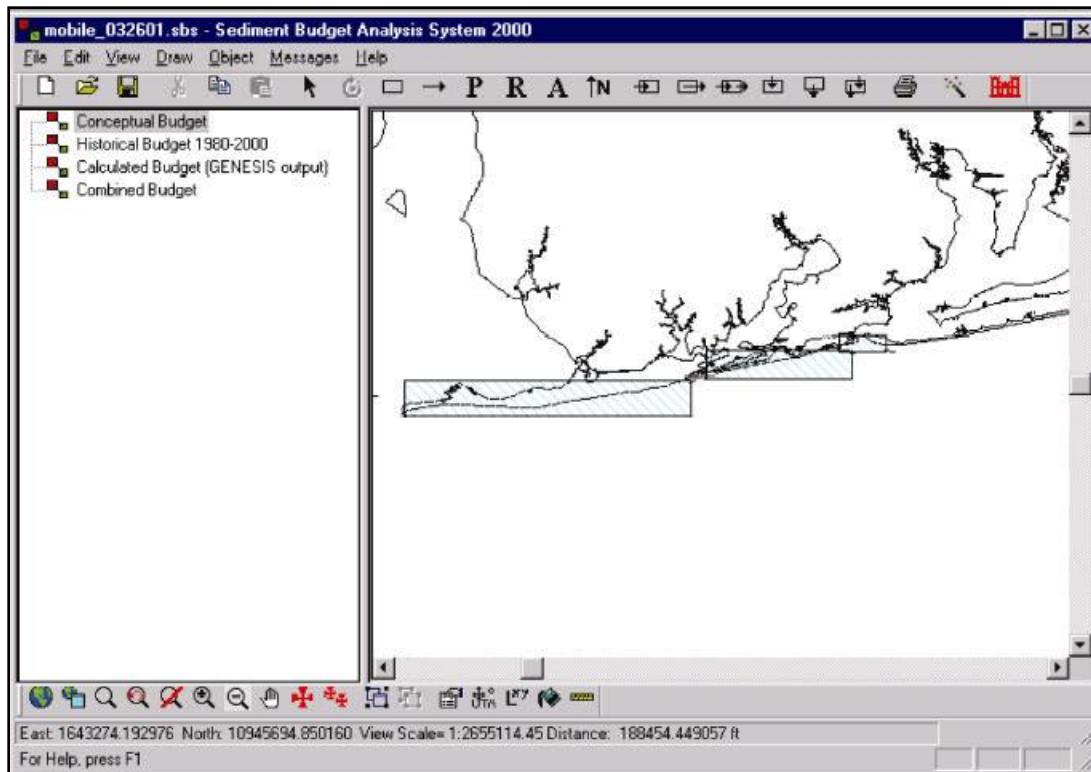**Figure 6.   Regional view of a sediment budget (zoom out), with alternatives.**

Figure 7. Local view of a sediment budget (zoom in) showing combined ("collapsed") sediment budget cells.
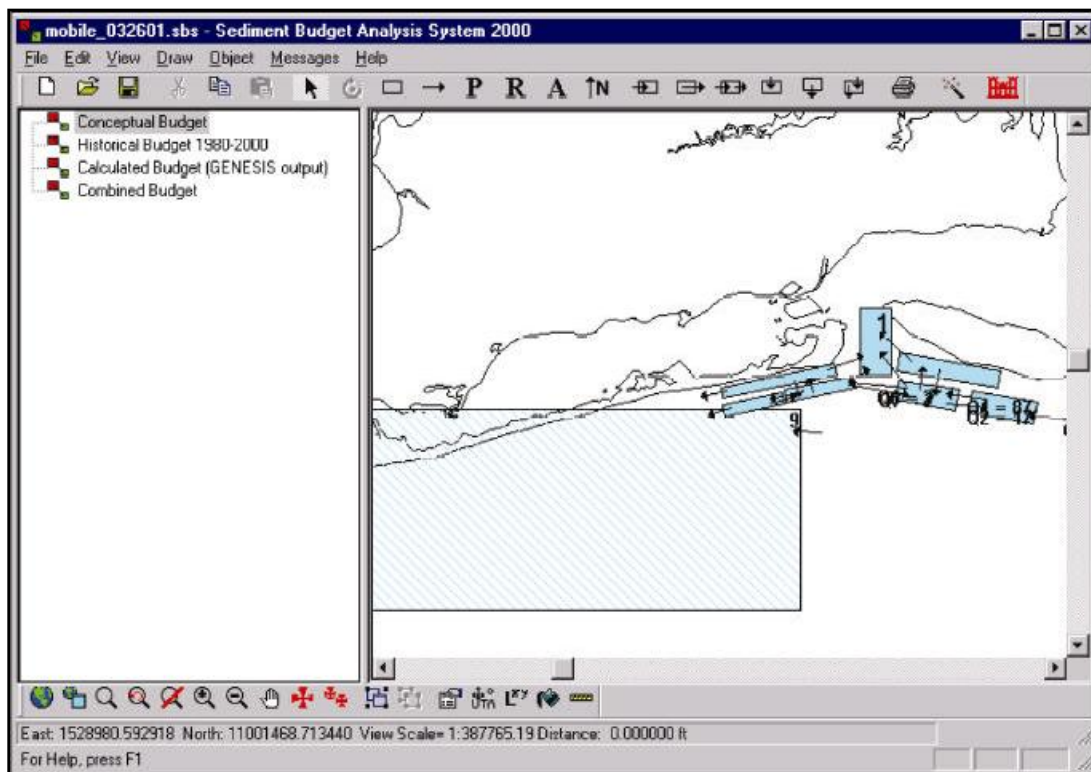

Figure 8. Sediment budget with reinstated ("exploded") cells.

SBAS can also display data on shoreline change and the rate of volume change associated with stations located along the coast, bay, or river (Figure 9). Station locations and associated data may be entered directly into SBAS's spreadsheet (Figure 10), or data may be imported using a user-specified format.

Geo-referenced images can be imported into SBAS by means of the *Load Map/Picture Layer* on the bottom toolbar. This menu (Figure 11) allows the user to indicate the coordinate system (group, system, datum, and linear unit) in which the sediment budget project will be defined. Next, the maps to be imported are selected, and their coordinate system is selected. SBAS converts the map's coordinate system to the project coordinate system. Multiple images (maps, aerial photographs, contour maps, etc.) can be layered in the sediment budget. SBAS allows for 55 different map coordinate systems.
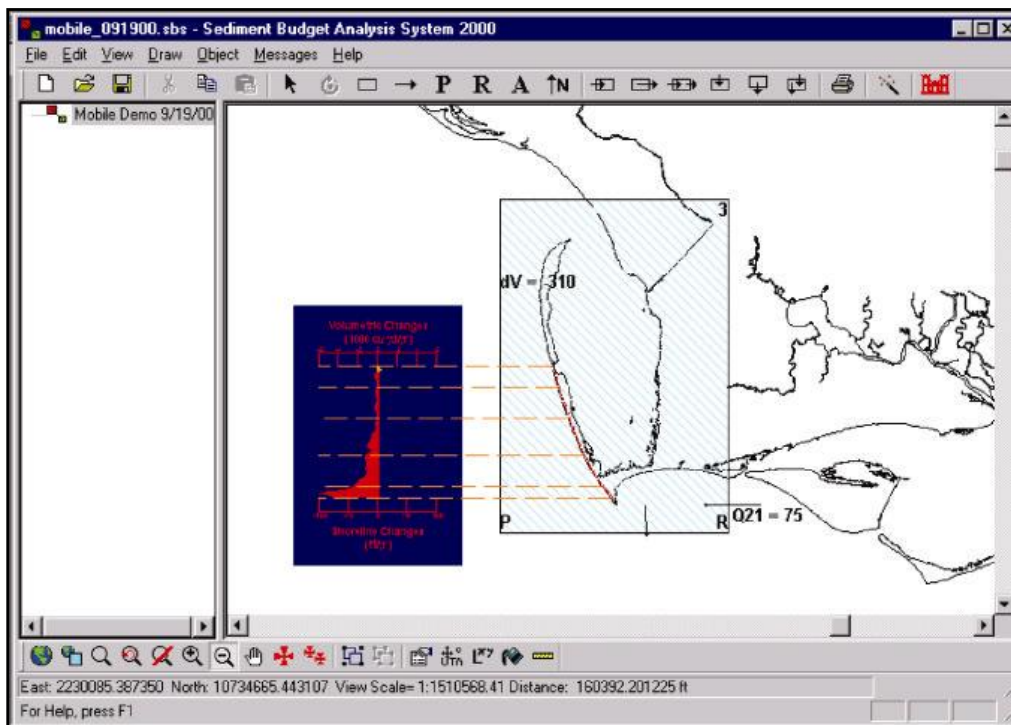

Figure 9. Rate graph feature of SBAS.

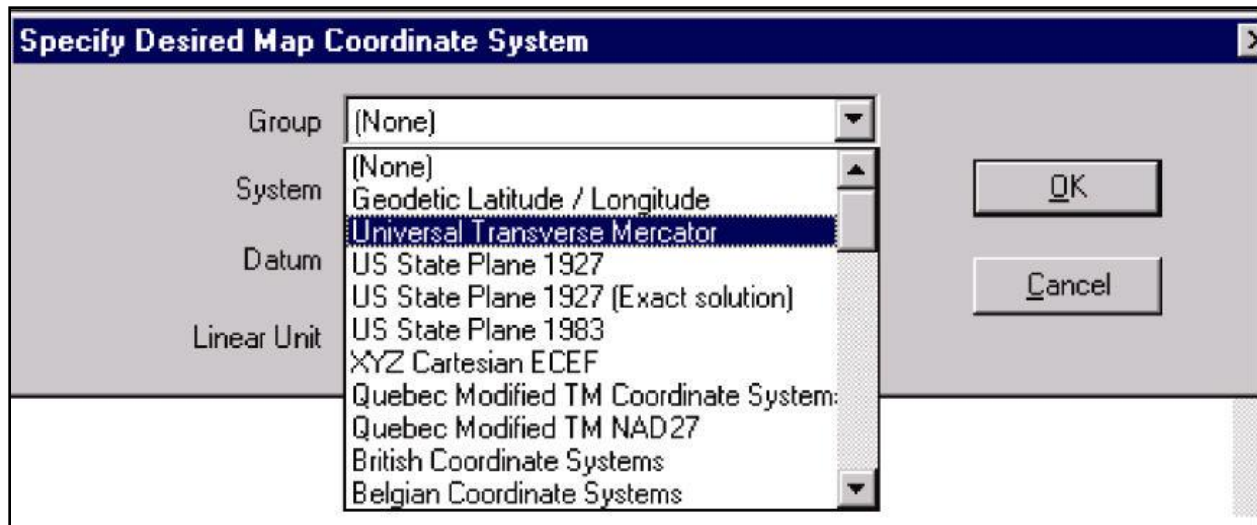Figure 10. Volume Edit spreadsheet in SBAS.

Figure 11. Entering project coordinate system with the Load Map/Picture Layer feature on the bottom toolbar.

EXAMPLE SEDIMENT BUDGET FOR HILLSBORO INLET, FL. The text that follows describes the operation and features of SBAS Version 1.02, available for viewing on the PC. The SBAS installation includes an example file with geo-referenced images, a sediment budget, and rate graph. The example problem, sediment budget development for Hillsboro Inlet, FL, guides the use of these files.

Step 1: Activate SBAS and Enter Information to the Document

Properties Menu. Information such as the manager of the project, keywords, units, and type of uncertainty calculation are entered into this menu (see Kraus and Rosati 1998 for details about the uncertainty calculation). Note that the user should choose the same project coordinate system and consistent units for the transport rate or volume change (e.g., if the project coordinate system will be in US customary units, rates should be expressed as cubic yards per year [yd^3/year] and volume as cubic yards [yd^3]).

Step 2: Import Geo-referenced Images. To import the map provided in the installation, activate the *Topology* window (right-hand side of the screen) by clicking in this area. Choose the globe on the bottom toolbar. The user first defines the desired project coordinate system as follows: **Group: US State Plane 1927**

> **System: Florida East 901**
> **Datum: NAD 27**
> **Units: USFEET**
> **Select OK**

Then, load the map provided in the installation with the Connect Map Layer menu. Select the following files:

> **Conus12.tif (image) and Conus12.tab (reference file)**

On the next menu, indicate that these files are in:

Group: Geodetic Latitude/Longitude
System: Latitude/Longitude
Datum: WGS84

(If the image is not visible, select "release zoom" on the bottom toolbar.)

Step 3: Import a Photograph. Choose the globe on the bottom toolbar and import another map layer. Select the following files:

Br21-38.tif (image), and Br21-38.tfw (reference file) (photograph of Hillsboro Inlet, FL, and associated world file)

On the next menu, indicate that these files are in the following coordinate system (same as the project coordinate system):

Group: US State Plane 1927
System: Florida East 901
Datum: NAD27
Units: USFEET

The coordinate system for the layers that have been loaded can be viewed by choosing the *Edit Current Selection Properties* button on the bottom toolbar.

Step 4:   Create a Sediment Budget for Hillsboro Inlet, FL. Access the top toolbar, select the cell button, and drag and pull sediment budget cells. Cells may be rotated to better represent different areas of the budget (the channel, for instance) by choosing the rotate button on the top toolbar and rotating a corner of a selected cell. Placement and removal in cells may be indicated by choosing the *P* and *R* buttons on the top toolbar, respectively, then clicking on the cell that has the engineering activity. Sediment sources and sinks to and from each cell may be indicated by selecting the arrow button on the top toolbar, and dragging arrows into and out of each cell as appropriate. Double-clicking on a cell will bring up the *Cell Properties* menu (see Figure 3), and values for each sediment budget element can be entered.

Cells can be collapsed by selecting the *Select Items to be Collapsed* button on the bottom toolbar, and dragging the cursor over the items to be combined. The cells may be reinstated by selecting the collapsed cell, then choosing the *Expand Collapsed Items* on the bottom toolbar. Note: colors of cell balance, gain and loss, arrows, and other sediment budget elements may be changed by selecting the *Object Colors* button at the top toolbar.

The sediment budget for Hillsboro Inlet, FL, can be formulated with three cells; (1) updrift, (2) channel, and (3) downdrift. The sediment budget has been summarized by Thomas D. Smith, US Army Engineer District, Jacksonville (personal communication), and has been conceptualized in Figure 12.
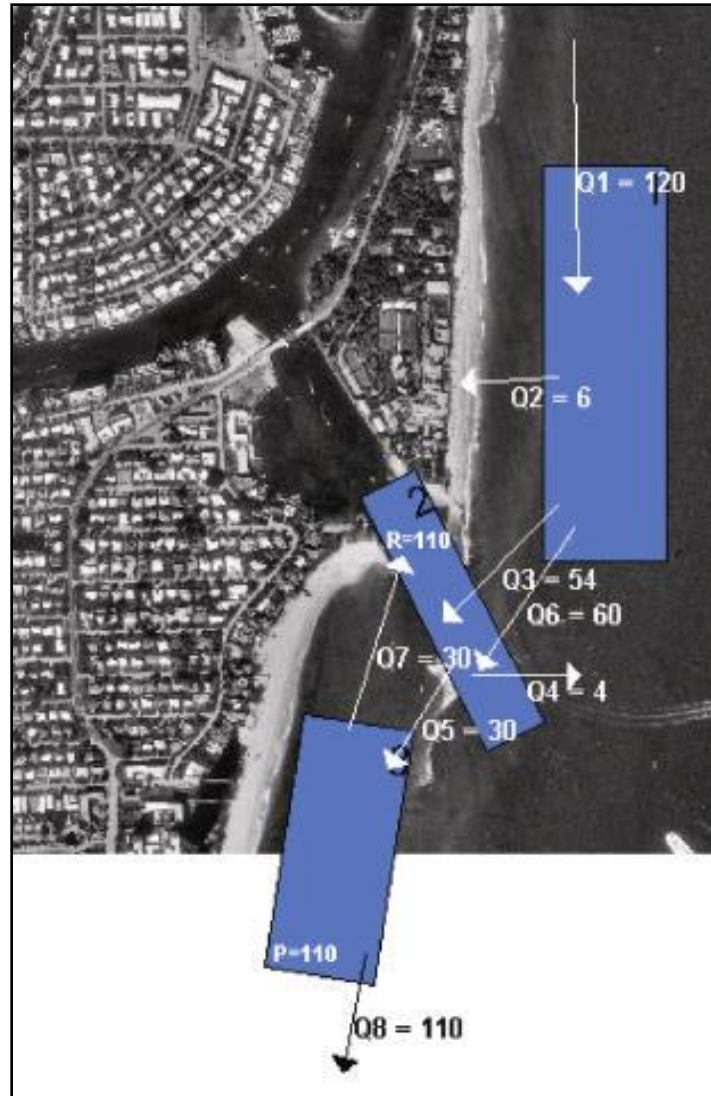
Figure 12. Sediment budget for Hillsboro Inlet, FL.

- *Updrift cell:* Net longshore sand transport entering the north boundary of the updrift cell is approximately 120,000 yd^3/year. Sinks from this cell include accretion of the updrift beach at a rate of 6,000 yd^3/year, 54,000 yd^3/year transported over the north jetty weir section to the channel cell, and 60,000 yd^3/year moving around the jetty into the channel cell.

- *Channel cell:* The source of sediment to this cell is 30,000 yd^3/year moving into the channel from the downdrift cell. Sinks from this cell include 4,000 yd^3/year transported to deep water on ebb flow, 110,000 yd^3/year dredged from the channel and placed within the downdrift cell, and 30,000 yd^3/year naturally bypassed from the channel to the downdrift cell.

- *Downdrift cell:* Dredged material placement into this cell is 110,000 yd^3/year, which is also the value of net longshore transport exiting this cell. The downdrift cell transports approximately 30,000 yd^3/year to the channel cell during periods of reversal, and also receives 30,000 yd^3/year from the channel cell that bypasses the inlet. The beach is assumed to be stable.

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Step 5: Enter Shoreline Change Rate Data for Hillsboro Inlet. Select the *Draw Stations* button on the bottom toolbar, and visually place benchmarks for shoreline data on the photograph. (If a pre-existing file with data is available, these station locations may also be imported to the SBAS Rate Graph spreadsheet). Once all stations have been entered, choose the *View-Rate Graph* button on the top toolbar, select the rate graph (named *Untitled* at this point), and choose *Edit.* Shoreline change (or volume change) data may be entered for each benchmark position. SBAS automatically plots these data in the rate graph. Selecting and dragging will move the graph, and de-selecting the graph after clicking the *View-Rate Graph* button on the top toolbar can turn it off. An example is shown in Figure 13.
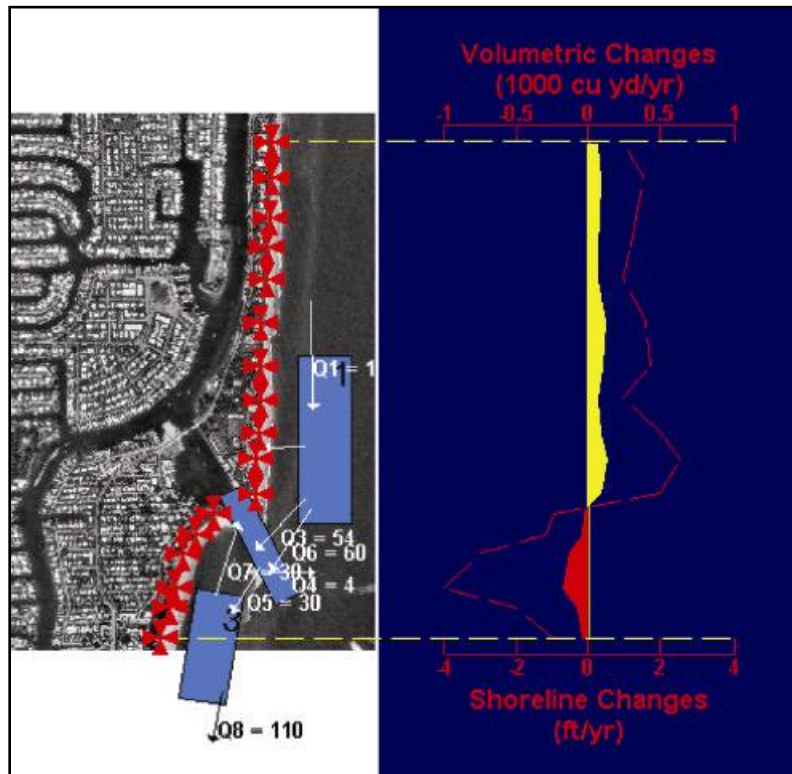

Figure 13. Hypothetical shoreline change data for beaches adjacent to Hillsboro Inlet, FL.

FUTURE VERSION OF SBAS. SBAS Version 1.02, described herein, is being modified to be an extension of ArcView©'s Geographic Information System (GIS), called SBAS-A. Linkages between ArcView© and SBAS-A will be transparent to the user, so that GIS data can be readily accessed within the sediment budget system. Both SBAS (non-GIS, described in this CHETN and in Rosati and Kraus [1999b]) and SBAS-A (extension of ArcView©) will be maintained and upgraded separately.

OBTAINING SBAS. Users in US Army Corps of Engineer Districts, Divisions, and Laboratories can obtain SBAS and the SBAS demonstration by contacting Alan Cialone (Alan.Cialone@usace.army.mil). The software is being distributed to other users (private consultants, academia, other governmental agencies) by a private company with whom the Coastal and Hydraulics Laboratory has a Cooperative Research and Development Agreement

(CRDA). A reduced purchase price has been established for school departments and students. For these users, SBAS2000 may be obtained from Veri-Tech, Incorporated, http://www.veritechinc.com. P.O. Box 568, Summit, MS, 39666, info@veritechinc.com.

ADDITIONAL INFORMATION. This Coastal and Hydraulics Engineering Technical Note (CHETN) was written by Drs. Julie D. Rosati and Nicholas C. Kraus, Coastal and Hydraulics Laboratory, US Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The research was jointly supported by the Coastal Inlets Research Program, Inlet Channels and Adjacent Shorelines work unit; and by the Coastal Sedimentation and Dredging Program, Regional-Scale Modeling Morphology Change and Sediment Transport work unit. Additional information pertaining to the Coastal Inlets Research Program (CIRP) can be found at the CIRP web site http://cirp.usace.army.mil and pertaining to the Regional Sediment Management (RSM) program can be found at the RSM web site http://rsm.usace.army.mil

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